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Studies on the vegetation of New York State—II. The vegetation of a glacial plunge basin and its relation to temperature *

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(WITH THREE TEXT FIGURES)

A striking feature of the topography of the region immediately about Syracuse, New York, is the occurrence of numerous plunge basins produced by waterfalls during the later stages of the glacial period. The recently established Clarke State Reservation near Jamesville contains several of these basins; Green Lake in the Reservation occupies the bottom of a large typical one. Some of these are known to botanists acquainted with this region as the habitat of certain rare ferns, especially *Botrychium Lunaria* (L.) Sw. (*B. onondagense* Underwood) and *Scolopendrium vulgare* Sm. Maxon† and others have noted that these stations for *Scolopendrium* are always quite cool in summer. Some of these plunge basins show such remarkably low summer temperatures and display a vegetation so distinctly northern in character that a preliminary study of one of them was made during the summers of 1916 and 1917.

The basin studied lies near White Lake, six miles southeast of Syracuse. It is a natural amphitheater, elliptical in shape, with sloping sides; at the top or rim it measures about six hundred feet in length and four hundred fifty feet in width, and has a maximum depth of about ninety-five feet. Along part of the rim there are cliffs five to fifteen feet in height, and the slope begins at their foot; elsewhere the slope begins at the rim and descends at an angle of approximately thirty degrees until the opposite slope is met. The longer axis of the basin lies on an east-west line, and the bottom presents the appearance of a ravine running in that direction. The outlet of the basin lies to the southeast, where there is a notch about fifty-five feet in depth in the rim; this lowest point of the rim is forty feet above the bottom of the basin, which lies at an altitude of about six hundred ten feet above sea level.

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* The first of this series is a general discussion of the outstanding features of the vegetation of New York state as a whole; the citation to this is as follows:

Bray, W. L. The development of the vegetation of New York State. N. Y. State Coll. Forestry, Syracuse, N. Y. Tech. Pub. 3, 1915.

† Maxon, W. R. On the occurrence of the Hart's Tongue in America. Fernwort Papers 30–46, Dec. 1900.

The basin lies in rather thick-bedded limestone for its entire depth, and the slopes are formed of debris of this material. Throughout this region the rock is extensively fissured and it is probable that the underlying bedrock here is traversed by crevices, since water does not collect in the basin. Except on a considerable portion of the north side, where there is a rock slide, the slopes are covered by a thin layer of nearly pure humus. Under the conditions which occur here this soil is always moist and plant growth in the basin is not restricted by lack of available water.

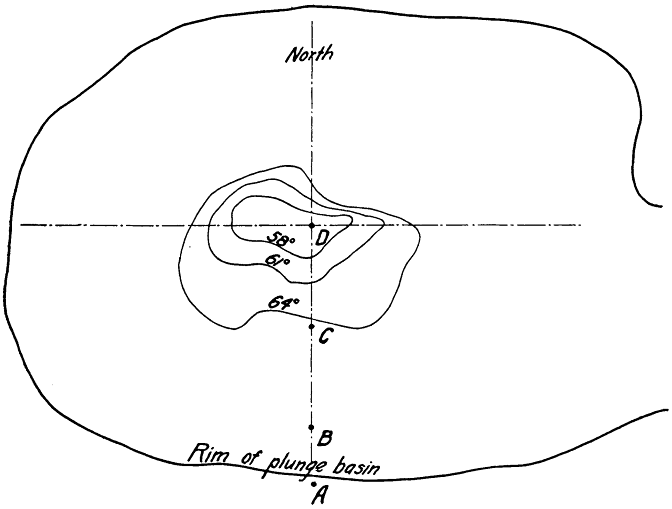

FIG. 1. Map of plunge basin, with isotherms of air temperatures (Fahr.) at 1 in. from the ground, at noon, September 12, 1916. *A*, *B*, *C* and *D* indicate location of stations referred to in the text. Scale, 1 in. = 160 ft.

The basin lies in a forest which has been somewhat disturbed by cutting. The interior of the basin itself is heavily wooded with *Tilia*, *Thuja*, *Betula lutea*, etc. The outlet is a narrow notch which extends only half the depth of the basin. As a result of these conditions, the bottom is completely free from air currents due to winds; even on a day when the local weather bureau station reported a wind velocity of thirty-five miles per hour, no movement of the air was perceptible half way down the slope of the basin. This absence of air currents is of prime significance in the explanation of the striking conditions of temperature that occur here.

Four stations for the securing of data on temperature and humidity were established in the basin. The first of these (FIG. 1, *A*) is six feet back from the rim, on the south side; it is in a forest of *Tilia* and *Acer saccharum*. The second station (*B*) is fifty feet down the slope from *A*; *Tilia*, *Scolopendrium* and *Impatiens* are the characteristic plants. Station *C* is one hundred feet further down the slope, while *D* is at the bottom of the basin, about one hundred feet below *C*. Temperature and humidity readings were made at each of these stations several times during the summer of 1916 and once during 1917; the data obtained on August 22, 1916, the hottest day of the year, are given in TABLE I.

TABLE I

TEMPERATURE AND HUMIDITY DATA AT STATIONS IN PLUNGE BASIN. AUGUST 22, 1916, 2.30–4.30 P.M.

Station	Temperatures (Fahr.)				Humidity (%)	
	3 ft. above ground	6 in. above ground	1 in. in soil	6 in. above ground	4 ft. above ground	6 in. above ground
A...	94.7	90.6	81.5	72.5	32	30
B...	90.0		76.6	75.2	32	37.5
C...	90.0	78.0	73.0	68.5	39	43
D...	63.5	59.7	51.3	42.5	73	71

The remarkable character of the conditions in the plunge basin is sufficiently shown by the data obtained at station *D*, where air temperatures were thirty degrees below those of station *A*, and where the soil temperature at a depth of six inches was only ten and one half degrees above freezing point. Readings made on other dates gave data similar to those of TABLE I, but in no case were any of the temperatures at station *D* higher than those given above. Similarly, the humidity at *D* varied from 75 to 85 per cent. but was at no time found to be below that recorded in TABLE I.

The cause of the low temperatures in the bottom of the basin is not clear, but is probably to be found in the accumulation of ice in underlying fissures. In the basin itself ice persists in the spring about a month after it has disappeared elsewhere. It is possible that a sufficient amount of ice accumulates in large crevices or fissures under the loose rock of the basin to maintain the low temperatures through the summer season. Some such localization of the areas of lowest temperature is indicated by the data on soil temperatures given in FIG. 2.

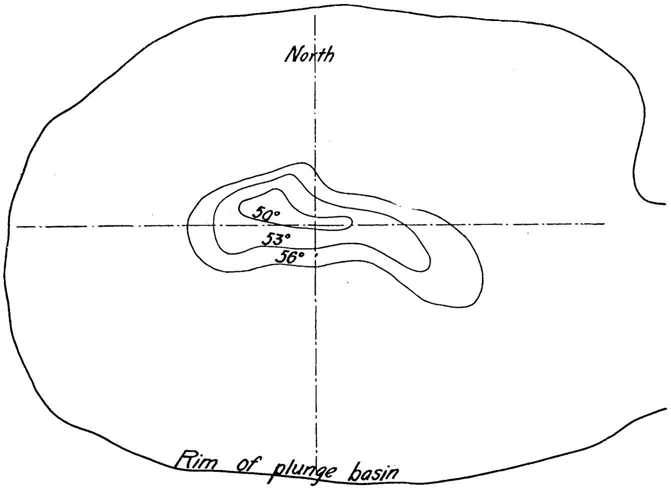

FIG. 2. Map of plunge basin with isotherms of soil temperatures (Fahr.) at depth of 1 inch at noon, September 12, 1916. Scale, 1 in. = 160 ft.

In order to determine with exactness the temperature conditions over the entire bottom of the basin, a system of twenty stations, at distances of thirty-five to fifty feet from each other, was established; these covered an irregular area extending about three hundred feet along the axis of the basin, some ninety feet up the south slope and about seventy feet up the northern slope. Two thermometers were placed at each station, one, completely shaded, at one inch from the ground, the other with the center of the bulb in the soil to a depth of one inch; after thirty minutes all the thermometers were read simultaneously.

When the temperature data are plotted on a map of the basin, isotherms can be drawn to represent the temperature conditions. FIG. 1 shows air isotherms representing the conditions existing between 11:30 A. M. and 12 M. on September 12, 1916, when the temperature at three feet from the ground at station *A* (on the rim) was 73° F.; Fig. 2 shows the soil isotherms of the same date. These are typical of the results obtained; charts made from the data obtained on other dates show that the isotherms vary but little in shape, only moving up and down the slopes within narrow limits with changes of temperature outside the basin. When the outside temperature falls below that within the basin the system of isotherms is of course destroyed.

As mentioned, *Scolopendrium* occurs abundantly in this basin, which is a typical habitat for it, associated with *Impatiens pallida* Nutt., *Asarum canadense* L., *Rubus odoratus* L., *Aspidium marginale* (L.) Sw., *Cystopteris bulbifera* (L.) Bernh., etc.; this association is restricted to the upper third of the south slope of the basin and is therefore outside the region of very low temperatures. The greater part of the basin is occupied by an association in which *Thuja occidentalis* L., *Betula lutea* Michx. f., and *Acer spicatum* Lam. are the dominant members; ground forms are few, mostly *Cystopteris bulbifera*, *Aspidium marginale* (L.) Sw., *A. spinulosum* (O. F. Müller) Sw. var. *intermedium* (Muhl.) D. C. Eaton, and *Thuidium* spp. The tree members of this association extend to the bottom of the basin but are less abundant there than farther up the slopes.

The forest floor association of the bottom area is the striking feature of the vegetation of the basin; a list of the species follows.

Dominant species

Cornus canadensis L.
Lycopodium annotinum L.
Dalibarda repens L.
Coptis trifolia (L.) Salisb.
Phegopteris Dryopteris (L.) Fée.
Pyrola asarifolia Michx.
Ribes lacustre (Pers.) Poir.

Incidental species

Lycopodium lucidulum Michx.
L. obscurum L. var. *dendroideum* (Michx.) D. C. Eaton
Aspidium marginale
A. spinulosum var. *intermedium*
Aralia nudicaulis L.
Tiarella cordifolia L.
Streptopus roseus Michx.
Actaea rubra (Ait.) Willd.
Diervilla Lonicera Mill.

Of these species, Bray, in the first paper of this series, lists three of the dominant ones as indicators of the Canadian zone—characteristic of the Adirondacks above 3,500 ft.—and four others as occurring abundantly in the Canadian Transition zone—characteristic of the higher Catskills and of the Adirondacks up to 3,500 ft.; and Cooper* lists four of the dominant species as characteristic of the climax forest of Isle Royale, Lake Superior. In addition, the manuals indicate a northern distribution for all the remaining species. These citations are sufficient to indicate the distinctively northern character of the plant association of the bottom of the basin.

Without entering into a discussion of the general questions of discontinuous distribution, it is evident that this may be considered to be a typical relict association, left behind at the final recession of the ice sheet. In this interpretation, certain conditions exist in this plunge basin which have caused or permitted the maintainance here of a plant association characteristic of more northerly regions or areas of higher altitude. That low temperature is the controlling factor of these conditions is the immediate and obvious conclusion from the data given above. This conclusion is strongly supported by further analysis of conditions in the basin.

During the work in the basin it was early noticed that the characteristic species of the bottom association are restricted to a common region of limited area and irregular shape; that is, the conditions which caused or permitted the maintenance of the association in the basin exist only in a small area of its bottom. As already described, the conditions of soil moisture, humidity, wind, etc., vary but slightly within the basin and cannot be controlling factors. The growing season in the bottom area is considerably shorter than in the upper part of the basin, due to the late melting of accumulated snow; the frostless period is probably about one hundred twenty-five days—an average period for the Canadian-Transition zone of Bray. This short growing season cannot however be effective in preventing the spread of the bottom association up the slopes of the basin, for not only do most of the species of the association spread readily by vegetative propagation, but ripe spores or seeds are also produced by most of them. On the other hand, the short season cannot be effective in preventing the invasion of plants of the higher parts of the slope, since these species have a longer season in which to mature spores or seeds, and every facility for their distribution into the bottom area.

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* Cooper, W. S. The climax forest of Isle Royale, Lake Superior, and its development. Bot. Gaz. 55: 1–44, 115–140, 189–235. 1913.

With regard to the temperature conditions, however, the case is different. Casual observation indicated that the characteristic species of the bottom association do not occur outside the region of noticeably low temperatures. To verify this observation the

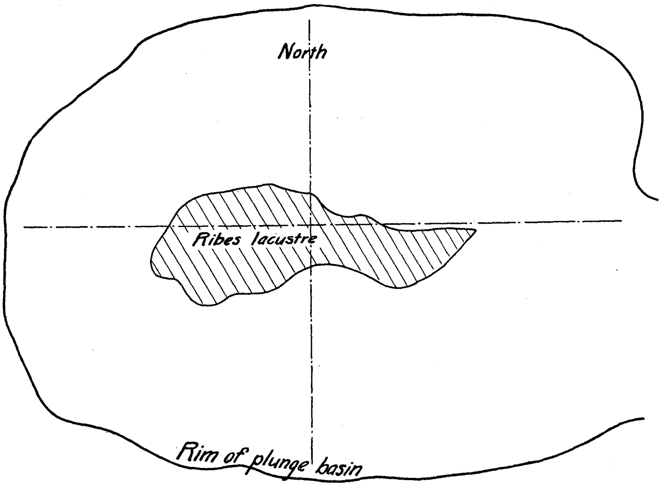

FIG. 3. Map of plunge basin showing distribution of *Ribes lacustre* (Pers.) Poir. Scale, 1 in. = 160 ft.

exact distribution within the basin of five of the dominant species was determined and plotted. The maps of the distribution areas are remarkably alike; that for *Ribes lacustre*, given in FIG. 3, is typical. By comparison with FIG. 1 it will be seen that the distribution area is only roughly that of low air temperatures, being extended farther along the axis of the basin. A comparison of FIGS. 2 and 3, however, shows a remarkable similarity between the outline of the distribution area of *Ribes* and the soil isotherm of 56° Fahr.; and the maps of the distribution areas of the other species show an equally close resemblance. This coincidence of the areas of low soil temperature and of distribution of five of the dominant species is held to indicate a direct causal relationship between the two. The writer is of the opinion that we have here a case in which the control of distribution of a plant association by the single factor of temperature is demonstrable; and that the plunge basin offers an exceptionally favorable opportunity to determine experimentally the mechanism of this control. Work is now in progress along this line.

SUMMARY

1. In the bottoms of certain plunge basins near Syracuse, New York, low temperatures prevail throughout the year. Data of air and soil temperatures are given for one such basin whose bottom lies at an altitude of six hundred ten feet above sea level; an area of some thousands of square yards in it remains throughout the year at a temperature below 70° Fahr.

2. The bottom area of this basin is occupied by an association of plants characteristically Canadian in distribution. Analysis of the conditions in the basin demonstrates that temperature is the factor controlling their distribution in this area.

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